*THE CLIMATE OF COLORADO FOR RESPIRATORY DISEASES.

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PART I.—THE ATTRIBUTES OF CLIMATE AND AIR-RAREFACTION.

The request of our Chamber of Commerce Committee, to give the facts concerning the kind of climate we have in the vicinity of Denver, is complied with reluctantly, only because the author fears his inability to do the subject justice in the space allotted. The evidence depended upon is too voluminous to mention it all, and the author will have to refer the reader to his other writings[1] for the details, and to state some positive conclusions, which might otherwise be challenged if they were not based upon a twenty-four years residence in Colorado, in which time some thirty-five hundred pulmonary cases have been recorded. Experience is what tells, and the experience of the medical profession in Colorado unquestionably sustains the conclusions here presented. We may differ as to the advisability of inviting the weaker, the invalid

[1] "The Rocky Mountain Health Resorts," Cloth and Paper covers. Houghton, Mifflin and Co., Boston, Publishers. Descriptive of the interior health resorts of the United States. "The Climate of the United States in Colors." The W. T. Keener Co., 95 Washington St. Chicago, Publishers. A graphic description, in twelve colored charts and eleven tabulations, of over 8,000,000 separate observations of the United States Signal Service Bureau, given in Annual and Seasonal representations of cloudiness, temperature, rainfall, winds and combined humidity statistics, for the professional and lay reference. "The Preferable Climate for Consumption." Congresses of 1876 and 1887. Somewhat elaborate arguments founded upon the analysis of climatic attributes independent of locality.

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class to come out here and live. The fact remains, however, that our recovered invalids have ceased to be a detriment to the communities in which they have mingled and that they constitute, in a large degree, the life and success of our new civilization. It is therefore with hope and confidence that we refer to the proofs which substantiate our experience in this elevated section.

Before proceeding with the summary of the evidence on hand, let it be admitted that some medical minds are not wholly in accord on the question of climatic effects in the causation and cure of disease, probably because of local bias or that their estimation of the attributes of climate is measured by a limited experience. This is unfortunate, but has to be admitted if any credence is to be given to such medical gatherings as the late "Congress of Medico-Climatology, Auxiliary of the World's Fair." At that meeting reports were presented from widely separated districts, high, low, inland, sea bounded and both within and without the United States. These reports were so exaggerated in praise of each special locality represented, that the listener, without a settled basis of judgment as to preferable climatic attributes, would be deceived into acquiescence to absurd propositions in turn alike contradictory. This going into the minutiæ of local weather statistics (as the daily range of temperature, or the extremes reached in a given month or year) as many have done, is of questionable use.

Such a mass of unessential particulars, however laboriously tabulated, only consumes time in its study and detracts from the consensus of knowledge needed.[2] [3]

Climate has to do with many special diseases, and

[2] To be commended: A recent historical and geographical study of the climates of that part of the world inhabited by the Engish-speaking people, issued by MacMillan and Co., London and New York, on "The Treatment of Lung Diseases by Climate," by Dr. C. Theodore Williams.

[3] "A Handbook of Medical Climatology" by S. Edwin Solly, M.D., M.R.C.S., Lea Bros. and Co., Publishers, Philadelphia and New York 1897.

its effects upon kidney diseases, the nervous system, age, sex and occupation would be instructive if time permitted to consider them; but we are now to study chiefly the class of diseases with which climate has both the greatest causative as well as curative effect, namely:

Chronic pulmonary diseases.—This study[4] of the air with regard to the causation and cure of respiratory diseases ushers us immediately into a controversy which has more than any other occupied the attention of climatologists for the past thirty years. It is the question of air pressure and the susceptibility or adaptability of the human organism to it under varying states of health and disease. Without seeming to controvert the great general argument, that of purity of atmosphere, always used by those who do not admit the importance of this air pressure consideration (for the pure air argument is an admitted issue and needs no proof), the question of altitude or sea level pressure can not, we believe, be ignored in the climatic prescription we are required to inscribe.

The purpose in the following presentation is to ignore any given locality and consider the chief attributes, those variously considered as most effective in the production of what is called climate. These are; 1, elevation above the sea (rarefaction); 2, dryness of the air, both absolute and relative; 3, temperature of the air, whether cold, cool or warm; 4, sunshine, its preponderance or average daily duration at a given place, which introduces the important questions of cloudiness and the diathermancy (clearness) of the air; 5, the winds which introduce many correlated causes, such as the seasonal changes, the configuration of the earth's surface at a given place, the ocean tide, storm winds, daily or periodical currents of mountain or sea air, etc; 6, the character of the soil, which is of great importance with reference to the proportion of forests to dry land, the contiguity of the sea or large

[4] Largely drawn from the Author's article on "Climatic Treatment" in Foster's Practical Therapeutics

bodies of water, and the general configuration of the earth's surface; 7, the variability or equability of the air-temperatures, which are largely relative, the former to altitude and the latter to the sea; 8, the electric condition of the atmosphere, which mysterious agent is also decidedly relative to mountain and sea currents, but which is none the less important as affording desirable stimulation.

In choosing from such attributes the most desirable combination for the arrest of lung disease, the writer feels called upon to explain why he does not place altitude the most important of all, at the head of the following list. It is; 1, because altitude shows its effect upon each important attribute, and thus in a fair analysis gets a reasonable allowance of praise; 2, because the special consideration of altitude is needed in presenting air-rarefaction as a potent force in treating respiratory diseases, hardly second, by itself, to any other attribute, yet at least entitled, in the minds of the majority of physicians, to hold the third place in such a classification.

Dryness is preferable to moisture.—We should have a line of demarcation between these two opposing qualities of the atmosphere, so that there could be no confusion in the use of the terms dryness and moisture. It seems that the average of the combined hygrometric conditions of the atmosphere, for the whole inhabited portion of the country, is a fair criterion between these two opposite conditions, and we will accept this as the line of definition between dryness and moisture. Temperature must be accounted for, as the capacity of the air to hold moisture varies so greatly, according to this record, the variation being from about one-half grain of vapor to the cubic foot, at zero, to nearly twenty grains at 100 degrees F., when the air is saturated. This was the foundation of the writer's rule for the determination of moisture and dryness.[5]

5 "Moisture and Dryness." Report made to the American Climatological Association, 1884. Rand, McNally and Co., Chicago.

This rule was based upon a calculation of a table representing the average of the combined humidities of the air (cloudiness, absolute and relative humidity) for the whole United States, and for every degree of temperature. The average of these three evidences of humidity were found to be 44.5 per cent. for the time (average proportion of each day) the sky was clouded, 67 per cent. of saturation, for relative humidity, and, consequently, 67 per cent. of the weight of vapor the air could hold, for absolute humidity.

The graphic illustration of this rule on colored maps, compared with mortality statistics, shows that the arrest of consumption is far more surely to be accomplished as you go toward the extreme of dryness, from the mean, than toward the extreme of moisture. Indeed, it is the very moist climates which furnish most of the cases to be arrested in the dry sections.

The chief argument in favor of atmospheric dryness is based upon the increased transpiration of aqueous vapor from the lungs, in a degree according to the dryness of the air breathed. The germs of disease need warmth and moisture in which to live and flourish, a climate tempered and constituted according to the requirements of their peculiar existence. It is reasonable to infer that the preference shown by tubercle bacilli for a *locus habitandi* in pulmonary tissue is in no small degree governed by the catarrhal or other products of inflammatory change which clog or close the air cells and connecting tubes. If these secretions or morbid products could be removed at the same time the bacilli which inhabit them were thrown off, the result would certainly be salutory. These could be so expelled if they could be reached by the inhaled air, and this in turn had the requisite absorbent power. This absorbent power is just what the inhaled air possesses through its quality of dryness, and in proportion thereto. Absorption takes place through the difference in percentage of saturation (relative humidity) between the inspired and the

expired air, and also much more through the difference in quantity (absolute humidity) between the moisture inhaled and that expelled. This especially takes place if cold air is inhaled, which is raised to the temperature of the body and then has greater power for holding moisture. Valentine, Sanctorius, Lavoisier, Seguin, Dalton and others have investigated the subject of transpiration, but not to differentiate between persons at different altitudes and temperatures. In this analysis of humidity statistics, ("Moisture and Dryness") the writer made an attempt to compute the difference in transpiration. He took Draper's statement as the basis of his calculations, namely, that the dew-point (the temperature at which the vapor present would make saturation) of the expired breath is 94 degrees, F. Three kinds of estimates were made by way of comparison.

1. Difference in vapor transpiration between a warm moist (Jacksonville, Fla.) and a warm dry climate (Yuma, Ariz.), of about the same elevation and temperature. This calculation, for an ordinary sized man, gave for Yuma, 3937 grains vapor exhaled, and 3073 for Jacksonville, or an excess for Yuma over Jacksonville of 864 grains a day, when no exercise was taken. When one makes allowance for the increased respiratory activity due to exercise, he can realize the still greater difference in transpiration as shown by Dr. Edward Smith's statement that, "one at sea level, walking at the rate of three miles an hour, consumes three times as much air as when at rest." The ordinary exercise of a man would make this difference in transpiration under the given conditions equal to about a gill in twenty-four hours.

2. When we make this calculation for places of different temperatures and elevations, the evidence becomes still more conclusive, for cold is probably the most important factor in the production of dryness, and elevation is not far inferior, because it, in turn, produces cold as well as expansion in the volume of the air. It is right to allow for the elevation

an equivalent to the proportionate rarefaction of the air, that is, if the pressure is one-fifth less (twelve pounds to the square inch) at Denver than at Jacksonville, then one-fifth more air will be breathed at the former station. In this calculation we will assume a good sized man, 30 years old, as breathing both in Denver and Jacksonville twenty breaths a minute and thirty cubic inches to a breath (Dr. Grehant), ordinary exercise included, and for the same season at each place. This gives by the same method of reckoning, vapor exhaled above that inhaled in twenty-four hours, 8900 grains for Denver and 4939 for Jacksonville. This is an excess of transpiration of moisture in favor of Denver of 3961 grains, or over 8 ounces, in twenty-four hours. Two important considerations would further add to this effect in favor of the high altitude station: *a*, the expansion of the air, in being raised in the respiratory tract from the lower temperature of the atmosphere to the higher temperature of the body; *b*, the increased amount of exercise naturally indulged in at the higher station, due to the stimulation of the cold, and the possible electric influence, quickening and deepening respirations.

3. For the purpose of still further comparison, it is instructive to take a cold, dry place in winter (Cheyenne, Wyo.) and a warm, moist one in summer (Charleston, S. C.) on the same basis (though Cheyenne is a little more elevated than Denver). The calculation results in vapor exhaled above that inhaled in twenty-four hours, 9881 grains in Cheyenne and 3615 in Charleston; excess of respiratory evaporation in favor of Cheyenne in winter, over Charleston in summer, is 6266 grains. If the two modifying effects previously mentioned were to be taken into consideration, together with the usually increased activity of the respiratory organs in such cold, as compared with such warm weather, the result would show for Cheyenne in winter a daily passing of vapor from the lungs of at least a pint more, than for Charleston in summer.

Coolness or cold is preferable to warmth or heat. The importance of cold in the composition of the curative atmosphere we seek is hardly less than that of dryness. In fact the two are so interdependent and necessarily associated that they can not be easily separated. If the thermal units coming from the combustion of effete material which should be thrown off through the lungs may be considered as indices of the natural cleansing of the system, then the tremendously augmented expenditure of heat units required in cold climates to maintain an equilibrium of bodily temperature must be credited for this great purifying influence. This potent effect is still further increased by the greater transpiration of vapor from the lungs in dry, cold climates, above proved to take place, because such transpiration is represented by the latent heat of vaporization, also necessarily thrown off. This temperature problem naturally introduces the following considerations:

1. How much atmospheric humidity is influenced by the element of temperature is shown by the sensory effect of cold. It is through conduction chiefly, that the body parts with its heat. Evaporation and radiation together do not equal this power of conduction, which the atmosphere, in common with everything that touches the body, possesses. Now, the conductivity of the air depends greatly upon its moisture. It is with the air as it is with solid substances. A bar of iron feels very much colder than the same shaped piece of dry pine, though they both may be of the same temperature. The iron is by far the better conductor, just as moist cold is, compared with dry cold air. To those who have never previously experienced a dry, cold and sunny morning on the eastern slope of the Rocky Mountains, there is a deception in the sensation of cold, which is equivalent to from 15 to 20 degrees. One seems to be in a much warmer atmosphere than that in which he really is. Temperature then is a relative attribute, and can not be considered as independent of humidity. Besides,

the drying effect of cold upon the atmosphere, low temperature will be found to have other useful effects in the arrest of consumption.

2. Heat expands the air, so that the contrast between the temperature of the atmosphere and that of the body indicates the swelling effect cold air produces when full breaths are taken. Any doubt about this may be settled by trying the simple experiment of breathing one's utmost into a spirometer in a heated room when the air is frozen outdoors. Then step to the door, take a full breath and try again; the difference should in part indicate the expanding force heat imparts to the inhaled air. This lung-stretching capacity of inhaled cold air is especially appreciated by those who hold that it is most often the lack of use which paves the way to infiltrations or tubercular deposits in the tops of the lungs. It is to such secluded places in the lungs that the expanding air carries the evaporating influence of dryness.

3. Cold stimulates and heat depresses. This is a generally accepted proposition, which needs no extended elaboration. The sensations themselves are a good guide, and the colder the air the more stimulating it is. "A bright sun and blue sky overhead, a clear and quiet atmosphere, distant sounds transmitted to the ear through the still air, combine with the charms of the scenery to produce such buoyancy of spirits that a man is braced and invigorated for almost any exertion." (Dr. A. Tucker Wise in "Alpine Resorts.") It is in harmony with this stimulating effect of cold, that the respiratory function is diminished in activity in hot climates, and an increased amount of blood is found in the lungs of residents in cold countries, as shown by Parkes, Rattray and others. Dr. Francis, of the Bengal army, found, from a large number of observations, that the lungs were lighter in Europeans in India than the European standard. The increased quantity of blood circulating through the lungs means increased oxidation of the blood and renewal of tissue. The pulmonary lymphatics join

in the increased activity, the nervous system is exhilarated, and the whole nutrition is improved.

Cold not only stimulates and encourages needed exercise, but under certain conditions it may result in a desirable sedative effect. The sleep which comes at night after a day's exhilaration and excitement induced by cold is the most refreshing of all rest.

The influence of cold in destroying or impeding germ life, especially the life of the bacillus of tuberculosis, is a most important consideration. This is diametrically opposed to the fostering of nearly all germ life by moist and mild heat. If one has ever "camped out" on the top of a Rocky Mountain pass, he will never forget the stillness of that insectless and germless locality. The nightly freezing of the air, together with its dilution through lessened air pressure, is enough to render germ life impossible. But the best evidence is that which has reference to the climate and natural life conditions of the bacillus, limited as they are to a narrow range of temperature.

"The air we inhale does not perhaps so often contain the fully developed bacillus as is supposed by many people, for this microbe does not thrive in the air at the usual temperature, but requires, according to Koch, a temperature approaching that of the human body. Its growth entirely ceases below about 82 and above 107 degrees F., and it thrives best at about 98 to 100 degrees, while other pathogenic microbes have a much wider field—for instance, the anthrax bacillus, which grows luxuriantly between 67 and 74 and up to 110 degrees."[6]

The study of seasonal effects in phthisis shows the salutary influence of cold. This may appear strange to those people of the North Atlantic, Middle and Lake States who flee south in terror of the winter weather. True, yet do not thousands yearly leave moist England for a winter stay in the frozen uplands of Switzerland? The force of this consideration is not

[6] Dr. Weber, in the "Croonian Lectures on Chronic Pulmonary Phthisis."

appreciated except through a recognition of the importance of dryness. Notice on the winter seasonal map, previously referred to, the prevailing northwest, west and southwest winds, some one of them everywhere moving toward the great interior lake region of the United States. The cooling of these air currents, causing condensation of vapor, with the addition of moisture already existing, is enough to produce cloudiness in this interior lake section for from six to eight-tenths of the winter season. The effect of the cold moisture renders this a climate to be avoided by enfeebled lungs. However, where the other attributes—dryness, elevation and sunshine—are favorable, the winter is the best time of the year for most consumptives. In cases suitable for positive treatment, these favorable climatic conditions, by means of this cooler temperature, can be increased to a climax of success not otherwise obtainable. The experience of invalids in Colorado bears out this conclusion. It is to secure the cooler temperature in summer time that some of the consumptive patients from the plains are sent higher up to the parks and divides of the Rocky Mountains. The effect of the change is very generally good, and a tubercular fire, which had rekindled in Denver on the advent of warm weather, has been arrested, as appearances indicated, by a sojourn in a cool park 8000 feet above the sea.

Rarefaction is better than sea-level pressure.—The consideration of elevation is divided into: 1, the effect upon other climatic attributes. Then aside from this there is the mechanical effect of rarefaction; 2, the physical influence upon man in health; 3, the influence in disease and the experience of invalids; 4, the evidence of a certain immunity from consumption.

We have already referred to the influence of rarefaction in producing dryness and coolness. Its effect upon sunshine, diathermancy, variability of temperature, wind movements, radiation, evaporation, etc., will appear as we proceed. The expansion of the air is equivalent, in degree, to any given elevation. The

additional space occupied carries with it its due proportion of atmospheric moisture. In localities favorable for health resorts, this deprivation more than counterbalances the condensation of vapor by cold. The result is a total decrease of moisture, which is shown by a small percentage of cloudiness, a low relative and a very small absolute humidity. Then through its expansive effect as well as by its influence upon other producers of dryness, elevation is a powerful agent in controlling atmospheric humidity. As to temperature, elevation has a constant effect in the production of cold. It is differently estimated by authors, but does not vary greatly from about 3 degrees decrease in heat for each 1000 feet rise in elevation. In some favorable localities, such as the eastern slope or base of the Rocky Mountains, this lowering temperature is neutralized by local conditions, such as the excess of sunshine, the character of the soil — being dry and sandy—and the protection of mountain ranges, which drain the western, humid air currents of their moisture, so that the isotherms, as a given elevation is reached, continue directly in a western course until the very high mountains turn them southward.

The physical effect of rarefaction upon human beings.—Dr. Jourdanet, of Paris, gave us a most complete and elaborate exposition of the physiologic effects of the diminished air pressure, and not content with this analytical investigation, he induced Paul Bert to work out by experiment, chiefly on the life of birds, the effects of the equivalents of various elevations, even up to starvation limits, as to the supply of oxygen. These and many other studies might be elaborated if space permitted. Ignoring their trivial differences, we will state only settled conclusions. Lessened atmospheric pressure leads to an equivalent loss of oxygen, which deficiency, Parkes, in his "Practical Hygiene," says is not felt by animals till a rarefaction equal to 14 per cent. is reached. This loss is about equivalent to an elevation of 10,000

feet, and many animals do begin to live an abbreviated existence at this height. But there are previous effects which man can appreciate all the way from 3000 to 6000 feet, at which latter limit the air is one-fifth rarefied. This appreciation, in a state of rest, is from nothing to considerable, according to the sensitiveness of the heart or lungs, or both of them. There is an adaptability of these organs in perfect health which more than compensates for a rarefaction of one-fifth, so that only a pleasant exhilaration is felt, even with moderate exercise. Much exertion strains this adaptability, and a degree of breathlessness may be reached, which indicates a decided deficiency of oxygen compared with the immediate requirements. However, it is not the point of injury or danger that is here referred to, but the altitudes which produce healthful and well-borne respiratory activity when at rest and even during moderate exercise. The effects of altitude vary according to the pulmonary or cardiac susceptibility of an individual, and are divided into, 1, first effects; 2, permanent effects or acclimatization.

On the arrival of a healthy individual in a high altitude, say a mile above sea level, there is first an increase, both in frequency and depth of respiration. When adjustment to the new conditions has taken place, which requires a variable period, according to the altitude and the individual, the respirations are not nearly so much increased in frequency during rest, but the depth of breathing is habitually greater. This is shown by the large spirometric records of those who reside at great elevations, and the increased size of their chests both in adults and children. This is farther shown by the necessity of the climatic change to supply the usual, if not augmented, demand for oxygen, which is to meet an increased combustion or change of tissues. The increased exhalation of carbonic acid and the lower air temperature, as well as the increased chest measurements in those invalids who are not so far advanced in disease but that the affected lung tissue can be returned to use (an effect

noted in the writer's cases, as well as those of C. T. Williams, Weber and others), are in perfect accord with the habitual use of more air for all the purposes of living in high altitudes. The heart and lungs having a reciprocal relation to each other, are both proportionately more active. In imperfect respiratory states, such as incipient consumption, the impeded circulation feels the stimulation, especially in those portions of the body which were the least active before —in the lung periphery and the capillary system generally. The result is a more perfect circulation of the blood and oxygenation of tissues, also of carbonaceous and effete materials. The supply and waste are more completely attended to, and the "sewer work" of the respiratory system is more complete. There is a change in the relative density of the air in the lungs, due to this increased activity and to the fact that the air breathed is rarefied. There exists an alternate greater pressure or density of the air with expiration, and diminished pressure or rarefaction during inspiration, with each respiratory act, compared with the air pressure outside the body, and also compared with the usual change of density of air in the lungs during respiration at sea level. Here is found the best form of "pneumatic differentiation" because it is natural. This increased outward pressure within the lungs is especially salutary in the chronic thickenings, etc., of the lining membranes of the air cells and bronchial tubes, and it has a tendency to open up passages closed by disease and non-use to the entrance of pure, dry air. Some of the worst cases of consumption are those where the air can not reach the microbes or morbid products.

The augmented respiratory activity.—This with the rush of blood into and through the pulmonary capillaries, which seem to disturb the judgment of a few physicians with reference to the liability to the occurrence of pneumonia or pulmonary hemorrhage in high altitudes, requires some further explanation.

There is no cause for fear of hemorrhage if proper precautions are taken as to extreme elevations and the character and stage of the disease existing in the lungs. There should be no spots of softened lung tissue, especially near the root of the lung which have not had time to be protected by nature's great conservative process—the deposition of fibrous or hardening tissue. Only those patients should be sent to very high places who can bear the rapid expansion and augmented circulation without rupture of blood vessels. In portions of the lungs where there is no softening this increased pressure acts helpfully on the distended vessels, just as a properly adjusted bandage does on a swollen limb. The alternate crowding of the dry air against hypertrophied or diseased alveolar walls, and the suction directly applied through the push given to the circulation, tend to clean out the products of morbid processes and relieve congestion. There is, as mentioned by Dr. C. T. Williams, 1, hypertrophy, or more complete development of certain portions of healthy lung tissue; 2, emphysema (dilation) of other portions, especially of those in the neighborhood of the consolidations and cavities. This increased action and the stretching help to isolate caseous or tubercular portions, prevent the spread of infection, and promote cicatrization or fibrination of the affected parts.

As to pneumonic and hemorrhagic cases, the writer's later experience tallies well with that tabulated in his report to the International Medical Congress of 1876, in which were presented his first records of 202 consumptives who had spent a total of 350 years in Colorado. The pneumonic cases and the hemorrhagic, without cavity, were by far the best influenced of all varieties. Very acute cases, during the time inflammation or hemorrhage is active, need to be treated upon the rest principle, and such should be excepted from the foregoing.

Altitude of immunity from phthisis.—There is presumptive proof that those climatic conditions which

prevail where phthisis seldom or never originates are best suited to arrest the disease when it has commenced elsewhere. Reference must be briefly made to the considerable evidence of medical writers in favor of an altitude of approximate immunity from consumption which, with us in America, ranges not far from 8000 feet in the southwestern part of the United States; to nearly 5000 on our northern boundary.

As to the quality of the climate which affords this partial immunity, Jaccoud of Paris, says, "altitude is the most important element; climates with a high altitude, having tonic and stimulating effects, can alone confer on the inhabitants absolute or relative immunity from pulmonary phthisis." While altitude is the governing element, all the associated favorable conditions of the atmosphere, somewhat in the order in which we have named them, seem to go hand in hand until they reach a climax of success in conferring a more or less complete immunity from consumption upon the residents at the given altitude. In illustration of this influence, the records of mortality from phthisis in the city of Denver and in Colorado generally, might be cited. Up to the year 1896, out of twenty deaths from this disease, eighteen or nineteen were from the imported cases, a fact which should always be taken into account as explaining the mortality from consumption in this State. Since the date given, the consumptive mortality in the city of Denver has shown an increase undoubtedly due to local conditions in which a greater liability to infection has to be admitted. Even thus the proportion of indigenous cases of tuberculosis to all deaths is now and for some time will continue to be far below that of any American city of like size.

Sunshine is superior to cloudiness.—There is little necessity of advocating the utility of sunshine. Proof is sufficient, but is necessarily combined with that of other climatic attributes. Every one acknowledges the benefit of sunshine, though in summer time he may have a personal preference for shade. Undoubt-

edly the effect of light upon man's physical and moral well-being is analogous to the fructifying influence of the sun's rays upon the vegetable kingdom. All life depends upon sunshine, and for successful existence must have it. The proportion of sunshine to cloudiness depends on the length of the day, on the exposure of a place, as on whether or not it is concealed in a valley, and on the cloudiness of the sky. The distribution of clouds in the United States is computed by the Signal Service Bureau in tenths of obscuration of the sky, and from these observations the percentage of cloudiness, and conversely of approximate sunshine, may be noted for the whole country. Reference is made to the first of the charts in the "Climates of the United States, in Colors" already referred to, for an eleven year average of the distribution of cloudiness. The variations of cloudiness range from above 60 per cent. of the time over the interior lake region down to less than 30 per cent. in the southwestern portion (New Mexico and Arizona). Taking so broad a field into calculation, a striking harmony is noted between cloudlessness or sunshine, and other favorable attributes. They all go together. A preponderance of sunshine should be mentioned as favoring the possibility of the desirable outdoor life, and also of camping out in summer time.

PART II.—SENSIBLE TEMPERATURE AND THE EXPERIENCE OF INVALIDS, WITH CONTRAINDICATIONS FOR THE HIGH ALTITUDE CLIMATE.

Variability versus equability.—The study of temperature ranges assumes importance from the undue weight given by the medical profession and the laity to supposed injurious effects of thermal changes. Let us investigate and see if it is the dampness and not the thermal oscillation which is responsible for the injury. How uniformly variability goes with dryness and equability with moisture may be illustrated by the daily and monthly ranges of temperature at places which represent dry and moist climates.

Chosen without reference to this particular evidence, twenty-five *dry* and twenty-five *moist* prominent signal stations and health resorts in the United States give the following remarkable average excesses of mean daily temperature ranges. The excess of the dryest one-fourth over the moistest one-fourth of them is 22.9 degrees, and the same average excess for the monthly ranges of temperature is 2.1 degrees greater variation in the dry than in the moist localities.

Again, taking the fifteen *most* and the fifteen *least variable* signal stations in the United States (out of 136 stations) for the year, we have an average excess of temperature variability of the most over the least changeable stations for spring, 18.5; summer, 16.2; autumn, 17.6; winter, 16.5, and for the year, 16.8 degrees F. The first fifteen are *extremely dry* with daily average for the year of 28.7, and the second fifteen *decidedly moist* localities with a daily average variability of only 11.9 degrees F. This evidence is conclusive that variability goes with dryness.

Seasonal ranges of temperature likewise show the inseperability of equability from atmospheric moisture, and of variability from dryness. Compare the winter and summer temperature lines on seasonal charts. The sea is the great equalizing influence, and the colder land in winter turns these isotherms to the south for a considerable distance in the United States, viz., on the western boundary, about parallel with the coast. In the summer, however, when they leave the ocean, these lines are turned nearly as much to the north as the winter ones are to the south. The farther we get away from the humid influences the greater is the variability of temperature. It is not maintained that extreme variability should always be sought or that of two places, with all other advantages the same, the more variable one is the better. On the contrary, the less variable would certainly be preferred in cold weather. It *is* maintained, however, that variability is quite a uniform constituent of dry high places and that as the dryness predominates the marked

variability is less felt and is less, if at all, objectionable. On the other hand, marked atmospheric equability, wherever found, is *prima facie* evidence of excessive humidity.

The worst that can be said against combining variability with the favorable attributes of climate for consumption is that its defence is necessary in order to overcome a prevailing prejudice and to show that this variability is a *sine qua non* of the preferable combination. But there would be no excuse for advocating a false theory of climate, even if this one element were unfavorable. There is a prevalent exaggeration of the effect of temperature changes. The change gets the blame which rightly belongs to the element of humidity, which constituent is always excessive when a given change is injurious. For instance, a change of 20 degrees from a warmer to a colder temperature, with the relative humidity 50 per cent. does not equal in the sensation or shock to the system a change of 8 degrees with the relative humidity at 80 per cent. The former change does not produce saturation, but the latter does; so does a change of 5 degrees with the humidity at 90 per cent., and even 2 degrees with the humidity a 95 per cent. of saturation (see Glashier's table). Therefore it is the humidity of the air which, through conduction of heat from the body, makes a slight temperature change, with the air near saturation, equivalent to a much greater change with the air dry. It is one of the mistakes of medical antiquity for equability to be insisted on as a constituent of the best climate for consumptives, yet this seems to be a fallacy most difficult to correct. It is essential to insist upon equability for humid climates, but for dry, cool, elevated resorts it is out of the question. There is something wrong with the reasoning powers of an author who jumbles together climatic attributes so that his "ideal climate" has no real counterpart among the known climates of the world. The trouble is chiefly with the vague use of the words equability and variability. Until now

there has been no accepted line of definition between these two terms. This we should have. If the mean of variability for the whole country were taken as a just division, and the daily and monthly ranges of temperature were the criterion to decide by, we would then have a division line approximately represented by 18 to 20 degrees F. for the daily, and 46 to 48 for the monthly range, the same being in harmony with the dividing line between moisture and dryness on the writer's climatic charts. This is a fair line of division which is commended for general adoption, especially by those authors who write about equability as essential to pulmonary resorts.

Actual versus sensible temperature.—Captain W. A. Glassford, signal officer United States Army, Denver, Colo., has given much attention to comparing the actual with the apparent climate in Colorado. Omitting interesting but lengthy illustrations, he says: "Taking the city of Denver, we find that during the year there are 172 days on which the daily mean temperature is above 50 degrees F. and 64 days below 32. The 50-degree point is the lowest mean temperature which mankind considers comfortable, and it is the critical point as regards the growth and development of the most important staple crops. The same number of comfortable days prevail during the year at Albany, N. Y., as here, but instead of 64 they have 107 days with temperature below 32 degrees (freezing).

"Let us now turn to a few facts as to Colorado summers. Denver is on the line of 105 degrees extreme maximum temperature, that being the highest ever observed here. To the west of this line these extremes diminish and to the east they increase.

"I wish, here, to draw particular attention to the unfairness—unintentional to be sure—to which Colorado and the entire West is subjected in the official consideration and publication of its record of heat as affecting animal life, in that there is overlooked the important element of dryness, which moderates the

sensible effect of the extremes of heat as well as of cold. There are in all temperature records two elements—the sensible temperature or that which expresses the heat or cold felt by the human beings, and the apparent temperature, a mere record of how the mechanical thermometer is affected. It is the apparent that receives publication, greatly to the undue advantage of the East and the detriment of the West.

"Strange as it has always appeared to me, the people of the West have always allowed this thermal element of climate to rest upon a common standard for the East and West, where the resultant effects are so dissimilar, in that the important factor of dryness of the air is entirely overlooked. The West should insist upon the publication of the sensible temperature, that is, what is technically known as the reading of the wet bulb. We would understand then why the high thermal conditions, apparently the same, do not here cause the cessation of business, prostration or death to man or beast, as among our Eastern neighbors. The difference between the apparent and the sensible heat in this vicinity being many degrees, explains our extreme comfort, while summer prostration in the East is explained by their slight range of difference. The very highest official record of heat at Yuma, Ariz., is 118 degrees, but the sensible heat at the time—that in the reading of the wet bulb—was 32 lower or 86 degrees. In the Eastern States 86 degrees of sensible heat is not uncommon when the thermometer stands in the nineties."

Besides the quality of stimulation which is associated with variability, there is an important consideration in the purifying of the atmosphere which variability indicates. This happens through the alternate expansion of the air by heat and its contraction by cold together with the nightly chilling and sometimes freezing, which regularly render it inimical to germ life. The purity of the atmosphere which is represented by warm, moist and equable climates, is not to be compared with that purity which is repre-

sented by the opposite attributes. The first is where the temperature keeps within the limits of the microbe's needs, where sound as well as heat is smothered within a short distance and the sun's rays give a dusky red glow. The second, indicating a comparative absence of germs, is where exposed meat can cure and not spoil, where distant objects appear near and where the unobstructed rays of the sun give nearly as white a light as an electric lamp does.

Diathermancy preferred to dense, moist or smoky atmosphere.—This diathermancy is the clearness or transparency of the air, which is a decided indication of its purity. It is with the atmosphere as with water. The larger the lake, with perfectly clear water through which one can see to a great depth, the better is the evidence of purity. So a large area, having throughout a similar atmosphere, through which one can see to most remarkable distances, must indicate as its coldness, rarefaction and dryness do, that the purity is approaching the absolute. This increasing purity of atmosphere, the absence of dust, smoke or moisture with its attendant infusoria is a decided feature of elevation, because with each rise of 1000 feet an equivalent stratum of air has been left below and, according to Professor Tyndall, each higher successive stratum contains less and less of infusoria. Professor Miquel of the Observatoire de Montsouris, near Paris, has achieved a result in the analysis of the air which is very interesting in this connection.[1]

Miquel found the following numbers of bacteria in ten cubic meters of air taken as nearly as possible at the same time at the respective places: At an elevation from 2000 to 4000 meters, none; on the Lake of Thun (560 meters), 8; near the Hotel Bellevue, Thun, 85; in a room of the Hotel Bellevue, Thun, 600; in the Park of Montsouris (near Paris), 7600; in Paris itself (Rue de Rivoli), 55,000. These figures are certainly suggestive of the fact that atmospheric purity keeps pace with diathermancy. A rule for the average

[1] "Chronic Pulmonary Phthisis," by Hermann Weber.

change in diathermancy, for each rise in elevation, was devised by the writer in 1876 from consecutive observations of the sun temperature at 2 P.M. and at different elevations: *For each rise of about 235 feet there is one degree greater difference in temperature between sun and shade at 2 p.m., as shown by metallic thermometers.*

The distribution of atmospheric moisture closely coincides with that of the soils. The dry soils, the rocky and sandy portions of mountainous configuration, and the dry sandy loams, with rapid absorption of air vapor and radiation of heat, nearly represent the dry climates. *Per contra*, the clay soils and marshes of level sections, with their moist cold and the easy solution of organic substances, are closely associated with the moistest atmospheres, excepting where humid currents come from over large bodies of water. This correspondence with reference to broad areas becomes strong proof of the utility of our preferable combination of climatic attributes.

A mountainous country, aside from the benefit of elevation, has many advantages over a level region. Chief among these are the quick drainage, which allows of no detention of stagnant water, the greater surface of the earth exposed to absorb atmospheric moisture, the many faces of rocks, etc., favoring radiation of heat and reflection of light, the element of stimulation, both atmospheric and electric, the controlling of severe winds, the variations of scenery, temperature and exposure afforded and the facility with which one can indulge in climbing hills and in pleasurable out-door activities. When these advantages are compared with the moisture-retaining properties, the sameness, the "siroccos," the trade winds, and the "norther" of level regions, one easily chooses between them.

The changes in the atmosphere accompanying the variability of temperature of mountainous places are

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2 Rocky Mountain Health Resorts.

decidedly electric. There is an increase of electric tension and there is an easier and more frequent interchange between the positive electricity of the dry air and the negative quality of the ground and clouds. The condition is very stimulating. This quality in high altitudes is associated with light showers, especially in summer time when they are most needed to clear the atmosphere. The simultaneous whirl of a light wind, often seen at a great altitude, purifies by its substitution of an unused and fresh supply of air for that which may be impure. Where people crowd together in large numbers, the daily freezing of the air is the only sufficient substitute for a mild wind. We thus arrive at the conclusion that in densely settled sections continuous stillness of the atmosphere is only to be preferred in the freezing weather of winter. The warmer the atmosphere the more air movement is desirable.

It is where there is a total absence of land influence, as at sea and on islands far out, or on dry, sandy coasts, with favorable sea winds prevailing, that low altitudes may best be substituted for high ones. The malarial and organic emanations from the soil, which are a fruitful source of increased mortality from consumption (Buchanan and Bowditch), are thus excluded from the climatic calculation. The aseptic condition of the atmosphere out at sea (Miquel), its quality of stimulation, and the tonic effect of the change, including the improvement of appetite and digestion, are all akin to the best effects of high altitudes, though the elimination of septic germs is less perfectly performed.

The evidence of experience.—This is in harmony with these favorable climatic attributes. One difficulty is our inability to make use of statistics of low lands which are fair for comparison with those which have been tabulated for high altitude stations. We have to explain in this connection, that the term "cured" should be qualified as meaning a more or less permanent arrest of disease, and that the records

given, embrace only those treated during a limited period by any of the observers.

The tabulated records at hand of careful and trustworthy physicians, show the favorable results in both the Swiss Alps and in Colorado (4500 feet and upward) to be as follows: For all stages of the disease, of 247 consumptives treated in the Swiss Alps, 38 per cent. were "cured" among 72 per cent. benefited. In Colorado 462 cases, 35 per cent. are recorded as "cured" among 75 per cent. benefited. This slight difference in percentage should be explained as quite natural considering the variable times of treatment, and the diverse interpretations by different physicians of the extent of the disease and of the relief afforded. Colorado really has many advantages over Switzerland as an all the year round resort, and also in the facility afforded to graduate the altitude to the season of the year.

In conclusion it is apparent that the element of altitude is inseparable from the best climate for chronic pulmonary diseases. The natural question then follows: What is the limit up to which this combination of qualities can be carried that the best results may be obtained? This is a question of individual adaptability which has to be settled by the attending or consulting physician. The best method of settlement is to determine what conditions or diseases are suitable for the extreme or the preferrable combination of attributes, and then arrive at modifications or rejections of the high climate cure by a system of exclusion. This method is that always advised by the writer (Rocky Mountain Health Resorts), and is seconded by the extended experience of Jaccoud as given in his work on "The Treatment of Phthisis." Jaccoud's conclusions are in the main correct, but it must be borne in mind that they, like those of Tucker Wise, Hermann Weber, and most of C. Theodore William's records, pertain to a more northern latitude than we reason about in the United States. In the Engadine, in Switzerland, the limit of timber growth is at or

below 8000 feet, an elevation compared with a similar limit at or above 11,000 feet in Colorado. Here the gradual rise, the distance from the sea, and the peculiar protection of mountain ranges make the change from low levels less severe. Also, in America, we have an increased advantage over most of European high climates in that we keep up the curative effect by suitable increase of altitude in summer. Instead, they are compelled, as at Davos, St. Moritz, etc., to give up the chosen climate treatment during the warm weather. The plan of deciding if the preferable climate can be made use of in a given case by exclusion because of negative conditions will not be readily accepted by the over-zealous advocates of low climates. This is, perhaps, because generally speaking, the more reasons there are for exclusion from the better high climate, the less likelihood is there for an ultimate recovery. Besides, it is not always easy to decide what change of climate a given patient can have, because of the varying conditions to be weighed, both as to the patient and as to the climate. We have to summarize by saying that the preferable climate for the great majority of consumptives in the United States varies, according to the case, between over 2000 feet elevation in the north in winter, and 10,000 feet as a possible extreme in the southern portion in summer. As to patients, not omitting social and economic bearings, they vary also, all the way from those cases that are hopeless to those that are to prove curable. There must then, of necessity, be many very delicate and intricate questions to be decided by the attending or consulting physician Of course, then, any rule of procedure must be susceptible of much variation. The physician who takes the most factors into account and weighs them best will be most successful in the management of each individual case. With this broad proviso we will state some general reasons why a given invalid may *not* go to an otherwise preferable high climate, and thus emphasize those who *may*. Assuming that he can relinquish

home and business cares and is financially able to remain from four months to two years away from home, or better, perhaps, make a permanent residence where he recovers, then the following are what we may consider as possible contraindications to a climate above 5000 feet elevation, such as that along the eastern base of the Rocky Mountains from Wyoming through Colorado into New Mexico and northern Arizona.

POSSIBLE CONTRAINDICATIONS.

1. The coldest season of the year, intensifying the effect of altitude too much for very delicate and sensitive persons, coming from much warmer climates.

2. Advanced age of the individual, rendering acclimatization difficult; "senile phthisis" and the fact that the patients are too old and feeble to exercise out of doors.

3. A very excitable nervous temperament, aggravating the stimulation of the high climate, producing irritability, and possibly wakefulness in a few extreme cases.

4. The state of some women, because of a greater susceptibility and lesser adaptability to the change and to out-door life than men have.

5. Valvular heart lesions, with rapid action of the heart, especially with the previous exceptions. Diseases of the great vessels, such as aneurysm.

6. Marked and extensive emphysema, pneumothorax, and hydro-pneumothorax.

7. Active pneumonia and existing hemoptysis. If the pneumonia or the hemorrhage is recent, the contraindication amounts to little; if remote, such cases are usually favorable. If there is reason for doubt in any such hemorrhagic or inflammatory case, a gradual rise in elevation should be advised.

8. Very high body temperature, whether it is rather constant, as in some inflammatory states or in catarrhal extensions beyond a tubercular center in the lung, or whether it is regularly vacillating, *i. e.*, daily subnormal in the morning, and regularly up to 103 degrees

or more later in the day, especially in so-called catarrhal phthisis and in laryngeal tuberculosis (unfavorable cases anywhere).

9. Too extensive involvement of lung tissue in diseased action, *i.e.*, so that the healthy spirometric record is more than one-half abridged.

"Phthisis with double cavities, with or without pyrexia; cases of phthisis when the pulmonary area at low levels hardly suffices for respiratory purposes" (C. T. Williams).

10. The active stage of lung softening, if accompanied by daily fever, or in one of a decided hemorrhagic diathesis. "Quick consumption" with or without intestinal ulceration or albuminuria (without predjudicing such a case if the acute symptoms are abated).

A proper estimate and consideration of these ten possible modifiers of the high altitude prescription tend to give the physician confidence of success in sending to well chosen elevated regions, such as the plains and foothills about Denver, incipient and first-stage tubercular pulmonary invalids, particularly if they are hemorrhagic or inflammatory cases without high fever, persons not too old and of fair resisting powers, and those with advanced or third-stage disease with a unilateral cavity already well protected by a conservative fibrosis.

The time to remain in a climate in which recovery seems to have taken place is a more delicate question than is generally considered. This is because tuberculosis is apt to be rendered latent by the climatic treatment and by nature's healing plan—the fibroid or hardening process. It is often essential not only that a patient should reside permanently in the new immunity climate he has reached, but that he should adopt a new and outdoor active occupation, in order to obtain the best results. In less urgent cases, encouraged by the absence of all physical signs of disease during a year or more, by gain in weight and by normal spirometer and manometer records, patients may return to their former homes to live with com-

parative safety. Many, however, find themselves deceived as to their real condition when they return to their old haunts and confined occupations.

The three principal agencies of relief or cure of tuberculosis thus far discovered, independent of a possible specific (some modification of tuberculin) to produce immunity, are diet, exercise and climate. These, rightly employed, tend to render the disease latent or innocuous through the process of fibroid healing in the lung tissue. The body resistance is strengthened, but the tuberculosis being latent, the individual has the same fight to go over again (it may be with a more unfavorable outlook) if he does not accept and act upon the lesson of experience. His climate, occupation and his habits of life, as to exercise and feeding, must thereafter coincide with what he has found to be most beneficial in his health-seeking journeyings.

Asthma and hay fever.—The name "hay fever" is a misnomer as applied to the breathing disability of many people, since the growth of hay has to do with only a small proportion of these cases. The causes are various, and whether having to do with the flowering of apple blossoms, the pollen of corn or of the Roman wormwood, nervous shock or to the dustiness of "dog-days," the fact remains that four-fifths of these so-called "hay fever" subjects are prone to cough and asthma. The nature of the affection is, like asthma, of nervous origin, and the best mode of relief in many cases is, much like that of asthma, to get out of the region of excessive vegetation into the rarefied air of the mountains.

One of the most troublesome complications in some of these "hay fever" cases is the asthma. The author gives it as his opinion, based upon an extended experience in Colorado, that there is no cure for pure and simple asthma equal to a resort to a well chosen high altitude such as the cool, dry and sunny inland plains and lower mountains of Colorado.

There is a prevalent misconception about this question of asthma, which explains the non-recognition

of the above truth, by many sufferers or by their medical advisers. It is not well enough understood what emphysema is, that it is not asthma, but rather the result of it. Asthma is a nervous disease. It produces the undue spasm or contraction of the circular muscular fibers of the smaller bronchial tubes, and the consequent hindrance to the air-circulation, or free inspiration. On the contrary, emphysema is a mechanical state of the vesicular portions of the lungs which complicates such conditions as asthma, whooping-cough, bronchiectasis (dilated tubes) and bronchitis, until there exists a more or less permanent disability of the air-cells, leading to their over-distension and the loss of their natural elasticity. Hence the difficulty and incompleteness of expiration. The one condition — asthma — hindering inspiration, is helped and sometimes immediately relieved by elevation; while the other—emphysema—hindering expiration, is sometimes made worse by the same element of air rarefaction. This is because the affected air-cells and distended bronchial tubes in emphysema are still more crowded with air, especially under any physical exertion, by the necessity to breathe more air in the mountains, in order to get the required amount of oxygen. Therefore, those of the "hay fever" class who have, or are prone to asthma, might be expected to find much relief, or a cure for the time being, in the high altitudes of the interior of Colorado. Pure and simple asthma usually meets at Denver, or in the hills to the west, with an elevation, aided by the sparcity of vegetable growths and the pollen-producing plants, which prevents the spasmodic contraction of the bronchial tubes, and the cure for the time of sojourn is established.

Malaria.—The aid of the high climate in eliminating malarial poison from the system of a person so charged, is a subject worthy of notice. The suspicion that malaria, like la grippe, bears a near relation to tuberculosis is firmly fixed in the minds of some physicians. So the opposite climatic conditions to those

which produce the malarial complications are the more trusted to wear out these evils. It is rather a confirmation of this eliminating process that the chills, when one comes up here with them, are sometimes aggravated at first. The general result, however, is good. The elimination of the malarial poison, which many sojourners in Colorado from Texas and the Mississippi Valley have shown by their happy experiences does take place, constitutes the removal of one of the most fruitful sources of pulmonary consumption. Thus the fascination is explained which the high altitude climate has for many people, who have left behind them the "epidemic shades" of these low sections.

In sending invalids to Colorado, a correct diagnosis is an essential condition of success; for, the physician of much experience in high altitude resorts has to acknowledge that too many failures or limited recoveries can be accounted for by a previous neglect to duly estimate a lung disease as farther advanced than it had been announced, or by a failure to sufficiently recognize the damaging association of "mixed infections," such, for instance, as arise from other blood taints than tuberculosis, or from the non-recognition of the co-existent or causative effect of fermenting blood states, due perhaps to dyspepsia, or to the non-elimination of effete material, as in amenorrhea, with or without constipation.

Allowing patients to go to high altitudes as a *dernier ressort*, who have not a 5 per cent. chance of living six months anywhere, is strongly deprecated. It should be remembered that every rule has its exceptions, and the stated contraindications named may perhaps be neutralized by favorable circumstances, such as the best time of year for the change, previous experience of the individual in high climates or the combination of compensating conditions in the same patient.

The seasons.—These natural divisions of climate necessarily influence the journeyings of invalids, the

time of going as well as the choice of the destination. The lack of space here to introduce them, and the advantage of the medical advisers to have on hand an ever ready reference to all important seasonal weather records, leads the writer to refer for all these data to his seasonal humidity, temperature, rain, wind and cloudiness charts.

The question of the season of the year is one of no small importance, notwithstanding the general truth that the best time for a person to go is when he has to, because of the beginning of lung trouble and not as a last chance. For one who really needs the change, there is no better time than the present. The season of the year does not produce so much difference in the indications for a given invalid's hastening away as does the advance of the disease from incipiency, or the first stage, to the ominous second stage, when the lung is "going to pieces." While the summer is by far the most satisfactory season to be in our mountains, and the autumn is a good season to get acclimated to a given high altitude before cold weather comes on, yet many maintain that the best results obtained by those suited to the rarefied air cure, are secured in the winter season. On the other hand, others not so well suited, such as neurotic persons, those unable to exercise outdoors because of advance of disease or extensive fibrosis leading to marked dyspnœa, or those with too sensitive mucous membranes to stand the cold, stimulating and dry out-of-door air, may do well to modify the effects by going first, via Texas perhaps, to southern New Mexico, Arizona or California, during the months from November to March, intending to reach Colorado afterward.

To this conclusion then we have arrived, namely, that for the great majority of cases of consumption this adaptation will be most fully secured in the dry, cool, rarefied, sunny, clear and pure, though variable, atmosphere of a well chosen high altitude, such as is fittingly represented by the region along the eastern base of the Rocky Mountains.